United States
Department of
Agriculture

Forest Service

Pacific Northwest
Forest and Range
Experiment Station

Research Paper
PNW-321
July 1984

Estimators and Characteristics of Logging Residue in Montana

James O. Howard and Carl E. Fiedler

Authors

JAMES O. HOWARD is a resource analyst, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. CARL E. FIEDLER is a research specialist, School of Forestry, University of Montana, Missoula.

Abstract

Howard, James O.; Fiedler, Carl E. Estimators and characteristics of logging residue in Montana. Res. Pap. PNW-321. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; **1984.** 29 p.

Ratios are presented for estimating volume and characteristics of logging residue in Montana. They relate cubic-foot volume of residue to thousand board feet of timber harvested and to acres harvested. Tables show gross and net volume of residue, with and without bark, by diameter and length classes; by number of pieces per acre; by percent soundness; by product potential; and by degree of slope and distance to roads.

Keywords: Residue estimation, residue measurements, slash, volume estimation, slash utilization, residue management, Montana.

Summary

Interest in utilizing logging residue has resulted in an increasing number of assessments of the feasibility of using the residue to produce energy or conventional wood products at specific facilities. These site-specific analyses have revealed the need for a data base that permits a more flexible method of obtaining information on the volume and characteristics of residue.

This study developed ratios that can be used to estimate the volume of logging residue, based on volume of timber harvested or on number of acres harvested, for any specific location in Montana. It also provides data on the characteristics of logging residue that affect residue utilization for energy or other products.

The information is based on measurements of logging residue on 120 cutover areas. Sample areas were allocated to four strata (public land clearcuts, public land partial cuts, private land, and lodgepole pine). Results are shown by strata. Tables show gross and net (chippable) volume, with and without bark. An example of how to apply the data is provided.

Contents

Introduction

Energy shortages during the past decade have focused attention on finding alternative sources of fuel. Sources considered to be renewable have been given special emphasis. Of these, woody biomass has greater near-term potential than most others. Wood residue associated with timber harvest has drawn special attention as a major source of wood fiber. In the northern Rocky Mountains logging residue[1] that can be recovered in conjunction with conventional timber harvest operations appears to have the greatest potential for short-term utilization, both for energy and conventional wood products (Keegan 1981).

Assessing the feasibility of utilizing residue at specific locations requires reliable estimates of residue volume and characteristics for uniquely defined supply zones.

A recent study provides analytical tools and data for site-specific analysis of logging residue in Washington, Oregon, and Idaho (Howard 1981a, 1981b). Equivalent information has not been available for Montana.

A number of studies in Montana have developed information on the down, dead, and cull components of timber stands prior to harvest (Benson and Schlieter 1980, Brown and See 1981, Keegan 1981). Although these sources provide valuable information for forest residue conditions, they are not adequate for estimating volume or describing characteristics of logging residue within defined supply zones.

[1]See Glossary for terms used in this report.

This report presents results of a study to develop a data base for logging residue in Montana that would: (1) provide the means to make site-specific assessments of logging residue for either wood products or energy, and (2) provide parity in residue information with other northwest States, thereby aiding regional energy planning and assessment.

The study had two primary objectives. The first was to develop appropriate analytical tools for estimating the volume of logging residue for any uniquely defined supply zone in Montana. Volume estimators (ratios) developed in this study relate residue volume to both volume and acreage of timber harvest. One ratio gives the cubic-foot volume of residues associated with the harvest of 1,000 board feet of timber (CF/MBF). The other ratio gives cubic-foot volume of residue per acre harvested (CF/AC). An example is provided to demonstrate practical application of these ratios.

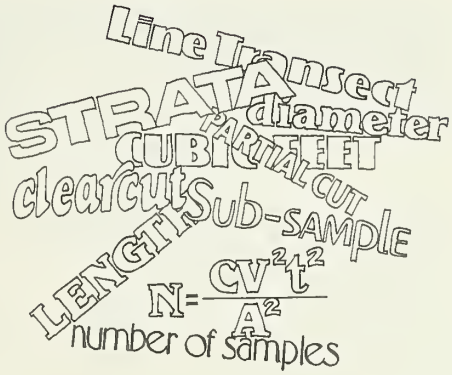
The second objective was to describe and classify logging residue by the following characteristics that affect utilization:

(1) Gross and net volume, by diameter and length classes, for live, and dead or cull material.
(2) Number of pieces per acre, by diameter and length classes.
(3) Volume by percent sound (chippable), in cubic feet per acre.
(4) Accessibility on cutover areas, by slope and distance to road.
(5) Volume, by product potential class.

Ratios and characteristics for residue are displayed for four strata. Three are based on owner class- harvest method (public—clearcut; public—partial cut; private—all harvest methods), one on forest type (lodgepole pine). These strata were selected on the basis of differences in residue volume associated with harvesting methods, and existing information on residue characteristics (Benson and Schlieter 1980).

Results are based on measurements of logging residue on 120 cutover units, made during the summer of 1982.

Study Design



Designing the study included the following steps: (1) determining sample size and allocation and selecting cutover areas to be sampled, (2) establishing procedures for sampling residue volume and characteristics, and (3) selecting procedures for computing ratios and characteristics of residue. Each of these steps is discussed.

Sample Size and Allocation

Sample stratification was based on timber ownership, harvest method, and forest type. Harvest data had indicated that there were three significant classes of owner and harvest methods in Montana. Only two classes of ownership, public and private, were identified. Most of the timber harvest on public land is on National Forests, and most of the harvest on private land is on industry-owned land. There was not enough harvest in any other ownership class to warrant a separate stratum. In terms of harvest method, only in the public sector is enough timber harvested by clearcutting to justify a separate stratum. Estimates of residue volume and characteristics for the private stratum represent the mix of harvest methods that were being used at the time of the study. This mix is not expected to change much from year to year.

A separate stratum based on forest type was used for lodgepole pine. Studies by Benson and Johnson (1976, 1980) indicate that residue in the lodgepole pine type is significantly different in character from that of other forest types. Lodgepole pine is also the most common species in Montana, occupying nearly one-third of the commercial forest land (Barger and Fiedler 1981). Furthermore, because lodgepole typically occurs in large, nearly pure stands, annual harvest and acreage can be identified in the data bases of major land owners.

The four strata identified for the study are:

Public, clearcut
Public, partial cut
Private, all harvest methods
Lodgepole pine, all harvest methods and land owners.

Following identification of study strata, the next step was to determine sample size for each stratum.

Sample size was determined by computation or rule-of-thumb, depending on available information.

Where information was available from which expected variation could be estimated, sample size was determined by the following formula:

$$N = \frac{CV^2t^2}{A^2};$$

where: N = stratum sample size,
CV = coefficient of variation
t = Student's t-value
A = desired level of precision.

The values for t and A were fixed so that the computed sample size would result in an estimated average residue volume per stratum within ±20 percent of the true average 9 times out of 10 (90 percent level). Coefficient of variation for logging residue volume (per acre) was used to compute sample size. This was done because the major contributor to total variance was assumed to be that associated with average residue volume (per acre). Values for CV were derived from previous studies where similar population characteristics were observed (Howard 1978, 1981a).

For the lodgepole pine stratum there was no comparable data from which estimates of variation could be derived. For this stratum sample size was set at 25. This number was considered adequate to provide results comparable to those from the other strata. Sample size determined for each stratum is shown below.

Stratum	Number of Samples
Public, clearcut	25
Public, partial cut	35
Private, all harvest methods	35
Lodgepole pine	25
Total	120

Sample Selection

Specific cutover areas were selected following determination of sample size for each stratum. The basic approach was to identify all cutover areas (the sample population) by stratum. The desired number of samples was then selected from this population.

The overall sampling scheme is a two-stage sample, with PPS (probability proportional size) sampling being the first stage. The second stage, residue sampling on each cutover unit, will be discussed later. In the first stage, PPS sampling was conducted for each of the four strata. Following PPS sampling procedures, all qualifying cutover units were listed, along with acres harvested. These acreages were accumulated, and random numbers used to select specific units for sampling. Under this procedure larger cutover areas have a greater chance of being selected, because each acre, in effect, has equal weight. Because sampling was done with replacement, some cutover units were selected more than once. For these units, residue measurements were made once, then replicated for each additional time the unit was selected.

Determining the sample population generally followed one of two procedures. For some ownerships it was possible to obtain a list of all areas cut over during the study period, January 1, 1981, to September 1, 1982. For other ownerships it was more efficient to use lists of *only* those cutover areas that met study criteria. Sample units were selected from those lists.

All cutover areas selected, regardless of which procedure was used, had to meet five criteria to be considered for study. Criteria were:

1. Logging was completed after January 1, 1981, and prior to September 1, 1982.
2. The unit was 5 acres or larger.
3. The unit had not been burned following logging.
4. The unit was not a fire salvage sale.
5. Logging residue on the unit had not been utilized by cull log salvagers, firewood cutters, or secondary operators.

These criteria were established to insure that residue estimates would be representative of normal harvesting situations.

A larger number of sample units was selected than dictated by the sampling process described. The extra units served as alternates to replace areas that failed to meet study criteria upon field examination. Alternate sample units for each stratum were used in the order in which they were drawn.

Following identification of the cutover areas to be sampled, each owner was contacted and asked to provide maps, location data, and information concerning characteristics of the area.

Specific information collected for each sample was:

1. Age of the timber harvested.
2. Acreage of the area harvested.
3. Type of logging equipment used.
4. Percentage contribution of the three major species harvested (set to 100 percent).
5. Volume of timber harvested, in thousand board feet per acre.

Residue Sampling Techniques

The average volume of residue on each cutover area was derived by three procedures. The line intersect method was used to obtain an estimate for scattered materials and small piles (Howard and Ward 1972). A pile

volume estimator, obtained from a separate study, was used to determine the volume in large piles (Little 1982). The volume of bark was derived by using bark-to-wood factors, obtained from a companion study (Snell and Max 1982). Information on characteristics of the residue was derived from a subsample of pieces measured for volume estimation.

Estimating scattered residue.—The line intersect method was used to estimate the volume of all residue material 3.01 inches in diameter (d.i.b.) and larger and 1.0 foot in length and longer, not found in large piles. The line intersect method has been widely used for estimating residue, and has been demonstrated to be efficient and unbiased (Pickford and Hazard 1978).

The sample design used in this study consisted of 200-foot line transects located at each of 30 points on a systematic grid (fig. 1).

The interval between grid points varied with size of the cutover area. Except on very large partial cuts, the fluctuating grid interval resulted in a pattern that covered the entire cutover area. The maximum grid interval was set to cover about 200 acres. For larger areas, yarding practices are such that residue piles are created throughout the area, rather than at a central location. Both scattered residue and piles, therefore, tend to be associated with the surrounding harvesting pattern. Thus, the sample design results in estimates of residue that are representative of the harvest practice within the grid pattern.

To reduce bias, both the initial starting point and the base line for the grid system were randomly selected. To reduce piece orientation bias (Howard and Ward 1972), each of the 30 line transects was randomly oriented along 45-degree azimuths.

Measurements were taken for all qualifying residue intersected by the 200-foot line transects. Only pieces at least 3.01 inches in diameter (d.i.b.) and 1.0 foot in length were considered measurable. Older dead pieces that were rotten to the point of losing their original form were excluded (fig. 2).

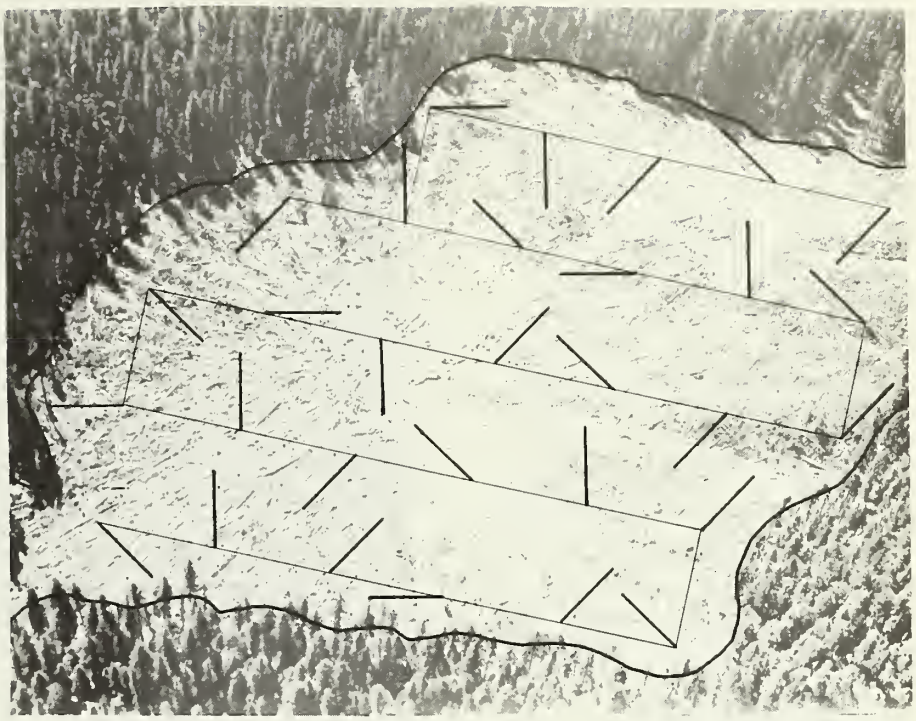


Figure 1.—Example of sampling grid for a cutover area.

Figure 2.—Deteriorated logs were not included in the study.

Measurements recorded for each piece of residue were:

1. Diameter inside bark (d.i.b.) at the point of intersection with a transect line.
2. Net chippable content at the point of intersection with a transect line.
3. Origin of the piece (live, or dead or cull at the time of harvesting).

These are the only measurements required to provide an estimate of gross and net volumes of scattered logging residue and small piles for a specific cutover area.

Estimating pile volume.—The line intersect method cannot be used to estimate residue in large piles (fig. 3), because many pieces in the interior of such piles are impossible to observe without taking the pile apart. Since destructive sampling of piles was not within the scope of this study, a separate procedure was used to estimate pile volume.

The procedure for estimating the volume of residue in large piles involved two steps. First, each pile was visually classified as one of four geometric solids shown in figure 4. Then the dimensions appropriate for the selected shape were recorded to the nearest foot.

The geometric volume of each pile was then computed from these measurements and converted to solid wood content according to procedures described by Little (1982).

Net (chippable) volume and origin of residue in large piles had to be derived by other means.

Net volume was derived by using data from an earlier study (Howard 1978) of residue from the harvest of old-growth timber with characteristics generally similar to those found in this study. The proportion of net volume to gross volume (0.54) from the 1978 study was applied to the gross residue volume of each pile to obtain net volume.

The proportion by live and dead or cull material in each pile was estimated by field personnel.

Figure 3.—Large piles of residue required separate procedures for estimating volume.

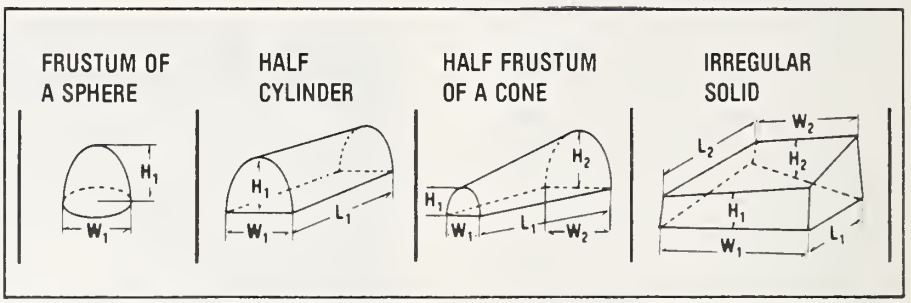


Figure 4.—Geometric solids and related dimensions used for estimating the volume of residue in piles.

Estimating bark volume.—Diameters of residue pieces were measured inside the bark (d.i.b.) to avoid problems associated with voids when outside-bark measurements are taken (fig. 5). Bark, however, is an important raw material, particularly for energy conversion. Thus another method was required to estimate bark volume. Ratios of bark-to-wood were developed for the major species, based on data from a study of bark samples from 50 cutover areas in Idaho, Oregon, and Washington (Snell and Max 1982).

A weighted average bark factor was computed for each sample unit using harvest volume by species. These ratios were then applied to wood residue volume to generate estimates of wood and bark volume.

Estimating residue characteristics.—To provide data on size and number of pieces and their product potential, additional measurements were made on a subsample of all residue pieces measured to estimate volume. The subsample consisted of all residue pieces encountered on the first 40 feet

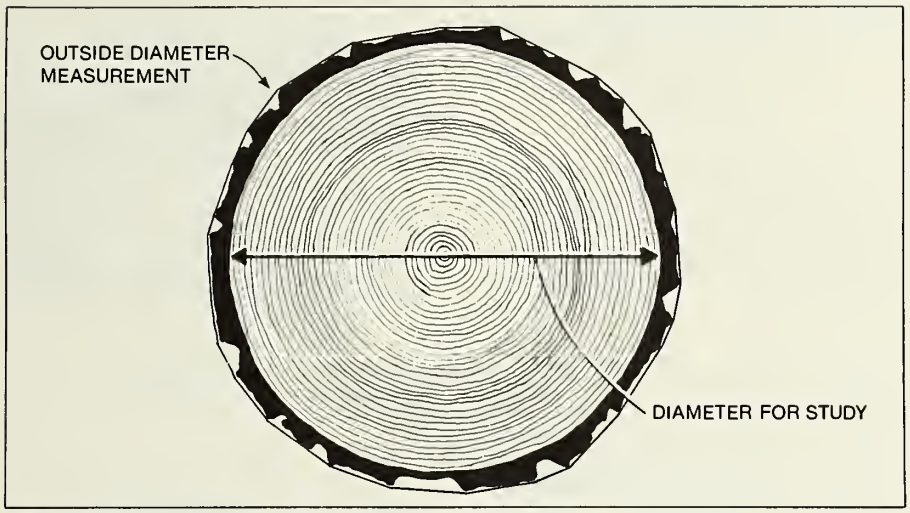


Figure 5.—Voids associated with irregularities in bark were avoided by making inside-bark measurements.

of each 200-foot line transect. This resulted in a subsample of 20 percent of the total number of pieces measured for volume.

The measurements for pieces in the subsample were:

1. Small end diameter (d.i.b.), to the nearest inch.
2. Diameter (d.i.b.) at intersection with line transect.
3. Length, to the nearest foot.
4. Net chippable content.
5. Live, or dead or cull at time of logging.
6. Product potential.

Items 2 and 4 were recorded both for the subsample and for the line-transect volume estimate.

Three classes of product potential were recognized, and recorded for all residue not in large piles. These classes were defined as follows:

Class	Product potential	Definition
0	Fiber only	Not meeting the standards for classes 1 and 2
1	Post or pole	minimum diameter, 3 to 6 inches minimum length, 8 feet maximum sweep, 1 inch 100-percent sound
2	House or saw log	minimum diameter greater than 6 inches minimum length, 8 feet maximum sweep, 1 inch 100-percent sound

Following completion of the transect measurements, all residue, including piles, was visually classified by the following slope and distance-to-road categories:

Slope: 0-35 percent
over 35 percent

Distance to road: 0-500 feet
501-1,000 feet
over 1,000 feet

Roads are defined here as any roadbed capable of handling log trucks and other logging-related equipment. In tractor-logged areas, especially those with flat terrain, acceptable roads are frequently of lower quality than those associated with steeper slopes.

Computational Procedures

The volume of residue recorded by the line-intersect method was computed by the following formula:

$$V = \frac{\pi^2 D^2}{8L} \cdot \frac{43{,}560}{144};$$

where: V = volume of each piece of residue, in cubic feet per acre (CF/AC);
D = diameter inside bark, in inches, of each piece of residue; and
L = total length of transect lines (6,000 feet).

The sum of the computed transect volume for each piece yields average gross volume (CF/AC) of residue for a specific cutover area. As discussed above, the volume of piles, where present, was computed separately. The total volume of residue in piles for each sample area was divided by the acreage of the area, to estimate the average of wood in piles on a per-acre basis. This figure was then added to the transect volume to obtain the overall gross wood residue volume for each cutover ara. Estimates of residue including bark were derived by applying the bark-to-wood ratios described above. Net chippable volume was computed from information collected for each piece tallied along the transects, and from the pile estimation process described earlier.

These computations provided estimates of residue in cubic feet per acre. A major objective of this study, however, was to provide ratios of cubic feet of residue to 1,000 board feet of timber harvested (CF/MBF). To obtain this ratio for a particular cutover area, the average volume of residue (CF/AC) was divided by the average harvest volume (MBF/AC). This is shown by:

$$\text{Ratio}_i = \frac{(\text{Residue volume})_i}{(\text{Harvest volume})_i}$$

$$= \frac{(\text{CF/AC})_i}{(\text{MBF/AC})_i}$$

$$= (\text{CF/MBF})_i ;$$

where: $i = i^{th}$ cutover area (sample unit).

Estimating average residue volume for a specific stratum required a further computational step. The use of PPS sampling, described earlier, results in the CF/AC-volume of each unit having equal weight. The estimate for each stratum, therefore, is the arithmetic average of all units in the stratum. This is represented by:

$$\text{CF/AC}_j = \frac{\sum_{i=1}^{n} a_{ij}}{n};$$

where: a_{ij} = per-acre residue volume for i^{th} sample in j^{th} stratum; and
n = number of sample units in j^{th} stratum.

The CF/MBF ratio for a stratum is similarly computed, using a ratio of the means approach. The formula for computing the ratio for a specific stratum is represented by:

$$\text{Ratio}_j = \frac{\dfrac{\sum_{i=1}^{n} a_{ij}}{n}}{\dfrac{\sum_{i=1}^{n} h_{ij}}{n}};$$

where: a_{ij} and n are as defined above for CF/AC_j; and
h_{ij} = per-acre harvest volume for i^{th} sample unit in j^{th} stratum.

Computing the volume for characteristics of residue is based on subsample measurements. The volume of each subsample piece is the same as that used for estimating the volume of the unit (CF/AC).

The gross volume of all pieces was summarized by diameter and length classes for each cutover area. A proportion was developed to relate the accumulated subsample volume to the total volume estimated from the line transects. This proportion was then used to adjust the subsample volume in each diameter/length class to reflect the computed residue volume for each cutover area. To obtain number of pieces per acre by diameter/length class, the adjusted volume for each class was then divided by the average piece volume for the class. Product potential was computed in a similar manner. The product potential of each subsample piece was coded in the field. The subsample volume for each product-potential class was accumulated and adjusted to the transect volume estimate by the method described above.

Net chippable volume for residue characterization was computed using item 4 of the subsample measurements.

Stratum averages of residue characteristics were computed in a manner similar to that described above. In effect, residue characteristics were developed, using all subsample pieces in each stratum and the average volume estimate for that stratum.

Residue Volume Estimators

Ratios for estimating logging residue volume are presented in two forms. One ratio relates the cubic-foot volume of residue to 1,000 board feet of timber harvested (CF/MBF). The other gives residue volume in terms of cubic feet per acre (CF/AC). Both ratios have value, depending upon the user's need and the availability of supporting data. Estimates of residue volume are obtained by applying the appropriate ratio to timber harvest volume or acreage for each stratum within the geographic area to be assessed.

A wide range of potential uses can be made of the tables, which show gross and net volumes of residue, with and without bark, and live versus dead or cull material. The appendix includes conversion tables for metric values and wood density and energy values for selected species. Also in the appendix are selected tables from a similar study conducted in Idaho, Oregon, and Washington. These tables are included to aid in comparing residue volume across the four-State area.

It is especially important to understand that estimates based on data from this report indicate only the existence of residue material. The availability of materials for conversion to energy, pulp, or other products depends on a wide range of factors, such as competing uses, intent of the landowners, environmental concerns,and cost. Many other factors influence the accumulation of residue but are beyond the scope of this report. Ultimately, it is the responsibility of analysts to determine the volume of residue that can be considered available.

Ratios of residue volume to harvest volume.—Table 1 gives the ratios of residue volume to harvest volume for gross and net volume of logging residue, with and without bark, for each of the study strata. Net volume represents the chippable portion of the residue, or that considered usable for fiber-oriented products. A variety of defects, such as cracks, checks, or early stages of rot, make much of this material unusable for solid wood products. Whatever product is considered, it should be recognized that some unusable material would have to be removed to recover the desired portions.

Gross volume represents the bulk or mass of logging residue, based on external dimensions. This measurement includes space not occupied by wood fiber, such as hollow logs (fig. 6) and pieces with splinters or chunks missing. Gross volume also includes material too rotten to have product value. The extreme example is a piece that has gross volume but no chippable material.

Gross volume is important to measure because it represents material that has to be removed or otherwise treated to reduce its impact on the site. Residue has impacts on reforestation, esthetics, environmental quality, wildlife habitat, stand management activities, and fire hazard. Given these relationships, a measure of gross residue volume is important in the broad context of residue management.

Estimates of gross volume of residue are also important for determining equipment requirements, and the cost of handling and transporting residue. While the net volume of residue represents product quantity and value, it is the gross volume that must be handled to recover the usable portions.

The volume of residue for a specific area can be estimated, using timber harvest data for the area and ratios available in table 1. A separate ratio and timber harvest figure should be used for each stratum represented in the geographic area being examined. These ratios, and other data in this report, are representative of current harvesting practices and markets

Table 1—Average gross and net volume of logging residue per thousand board feet of timber harvest by wood only, by wood and bark, and by stratum

Stratum	Wood		Wood and bark	
	Gross	Net	Gross	Net
	Cubic feet per thousand board feet of timber harvest			
Public:				
Clearcut	121	75	142	95
Partial cut	148	78	173	103
Private 1/	185	102	221	137
Lodgepole pine 2/	146	91	162	107

1/ Samples were selected from all harvest methods; most samples were from partial-cut areas.

2/ Samples were selected from all harvest methods and ownership classes.

Figure 6.—Hollow logs have gross volume, represented by external dimensions, that includes space without usable wood fiber.

and should remain useful as long as harvesting technology, stand conditions, and the current product mix do not change significantly.

The ratios of residue volume to harvest volume in table 1 are similar to those reported for Idaho in an earlier study (Howard 1981a). A comparison of the two studies shows the Montana ratios to be somewhat lower for public lands than in Idaho, but 15 to 25 percent higher for private lands. The CF/MBF ratios in Montana are generally higher than in the coastal areas of the Pacific Northwest. The opposite is true for per-acre residue volume, however, because harvest levels are greater in the coastal areas.

Also affecting the residue situation in Montana is the relatively high level of mortality in lodgepole pine stands. Log markets have not been able to cope with the large volume of recently killed lodgepole pine. Thus, where it is mixed with other species, the lodgepole may be cut but not as fully utilized, partly because of the relatively high number of small stems. The result is higher levels of residue than would otherwise be the case.

The following tabulation compares the net volume of residue to gross volume for each stratum:

Stratum	Net volume as a percent of gross volume
Public: Clearcut	62
Public: Partial Cut	53
Private	55
Lodgepole pine	62

The percentage of net volume is somewhat higher for clearcuts and lodgepole pine than for the other two strata, which are predominately partial-cut harvesting. The reason is that most partial cutting is oriented to a specific product or to a tree-class. Thus, material not sought is frequently not removed (previously down and dead material, for example). In clearcutting, however, nearly all trees are cut, exposing all timber to the possibility of removal, based on marginal product value of each piece. Material that was down and dead prior to harvest usually has more defect than green timber. Therefore, a higher average percent defect of residue would be expected for partial-cut areas.

Much of the lodgepole pine recently killed by insects had not incurred extensive decay at the time of this study. Lodgepole also does not have as much heart rot as other species have. These two factors result in a higher percentage of chippable residue.

Ratios of residue volume to area harvested.—Ratios of cubic feet of residue to acres harvested are valuable expressions of the quantity of logging residue. Per-acre volume is especially useful for making economic assessments and evaluating residue management alternatives. Table 2 gives the average gross and net residue volume per acre, by stratum, for wood only and for wood and bark. These data can be used to estimate residue volume when the number of acres harvested is known for a given stratum.

The information in table 2 can be used to compare relative densities of residue between strata to aid in setting priorities for utilization or treatment options. Greater concentrations of residue, for example, are generally more feasible to recover than small quantities. Thus, use of the above data would help identify broad acreage groupings having the greatest potential.

Historically residue volume has been expressed in cubic feet per acre. Thus where similar data are available, it is possible to determine trends in timber utilization, or conversely, residue levels.

Table 2—Average gross and net per-acre volume of logging residue by wood only, by wood and bark, and by stratum

Stratum	Wood		Wood and bark	
	Gross	Net	Gross	Net
	Cubic feet per acre			
Public:				
Clearcut	2,021	1,246	2,369	1,594
Partial cut	1,578	831	1,846	1,100
Private 1/	1,345	737	1,602	994
Lodgepole pine 2/	1,816	1,128	2,009	1,321

1/ Samples were selected from all harvest methods; most samples were from partial-cut areas.

2/ Samples were selected from all harvest methods and ownership classes.

Special relationships.—Tables 3 and 4 provide additional insight into residue. These data show the percent of residue that was dead or cull at the time of harvest and the percent of volume in large piles.

As noted earlier, the percent of residue volume made up of previously dead or cull material is higher on partial-cut areas than on clearcuts. This is borne out by information in table 3. Roughly 55 to 70 percent of gross residue volume was from trees that were dead or cull at the time of harvest. For net volume the percentage was somewhat lower. This is explained by the fact that both dead and cull material have more defect than green timber, and thus account for a lower proportion of the chippable volume of residue.

These data are especially useful in projecting timber inventories. Because material that was dead or cull before harvest has been accounted for by mortality and defect figures in current inventory data, only the portion of logging residue from live trees needs to be deducted to complete the estimate of inventory drain.

The data in table 4 show the relative contribution of the volume in large residue piles to overall stratum averages.

In Montana the percent of residue volume in large piles is higher than in all but one stratum in the three-State report(Howard 1981a). The Montana figures are comparable only with National Forest clearcuts in Idaho. Explanation of these differences is beyond the scope of this report. The differences emphasize the need to ascertain timber sales policies when studying the feasibility of utilizing residue.

Table 3—Material dead and cull (wood only) at time of harvest as a percentage of average gross and net residue volume, by stratum

Stratum	Gross volume	Net volume
	Percent dead and cull	
Public:		
Clearcut	54	40
Partial cut	69	53
Private 1/	63	48
Lodgepole pine 2/	65	55

1/ Samples were selected from all harvest methods; most samples were from partial-cut areas.

2/ Samples were selected from all harvest methods and ownership classes.

Table 4—Volume of residue in large piles as a percent of gross and net volume (wood only), by stratum

	Gross volume		Net volume	
Stratum	Average	Highest	Average	Highest
	Percent			
Public:				
Clearcut	22	89	19	87
Partial cut	12	89	12	90
Private 1/	25	85	24	79
Lodgepole pine 2/	29	82	25	80

1/ Samples were selected from all harvest methods; most samples were from partial-cut areas.

2/ Samples were selected from all harvest methods and ownership classes.

Tables 5 through 9 concern only residue that is scattered throughout the areas sampled and do not include residue in large piles. Table 10 pertains to distribution of all residue, including that in large piles. Six additional tables (13 through 18 in the appendix) provide a breakdown indicating whether the material was live or dead or cull at the time of harvest.

Volume by Diameter and Length Classes.—Tables 5 and 6 give the distribution of gross and net residue volume (wood only) for each of the study strata. The gross volume table represents material that must be handled, whether for product recovery or treatment. Net volume represents the chippable content of residue. Thus even if product recovery is the major objective, gross volume is an important consideration.

The data are reported here in cubic feet per acre because feasibility studies usually involve per-acre figures. In some situations it may be desirable to relate residue characteristics to cubic feet per 1,000 board feet of harvest volume. This can be accomplished by determining the desired relationship of gross or net volume from these tables and applying it to CF/MBF volume estimates on a percentage basis.

Table 5—Gross volume (wood only) of logging residue, by diameter and length classes and by stratum[1/]

Stratum	Small end diameter	Length (feet) 1.0-3.9	4.0-5.9	6.0-7.9	8.0-15.9	16.0-31.9	32.0+	Total
	Inches	Cubic feet per acre						
Public:								
Clearcut	3.0- 3.9	12	24	29	105	143	81	389
	4.0- 4.9	20	21	17	43	51	23	175
	5.0- 5.9	8	17	13	38	25	14	115
	6.0- 6.9	23	15	12	39	40	26	155
	7.0- 7.9	3	7	13	21	17	11	72
	8.0-11.9	19	36	33	77	69	46	280
	12.0-15.9	12	17	19	40	41	33	162
	16.0-19.9	4	0	17	43	37	19	120
	20.0+	8	13	0	18	51	15	105
Total		109	150	153	424	469	268	1573
Partial cut	3.1- 3.9	8	15	14	66	88	81	272
	4.0- 4.9	10	14	8	38	40	48	158
	5.0- 5.9	3	10	10	23	24	20	90
	6.0- 6.9	8	9	9	33	38	52	149
	7.0- 7.9	7	7	5	22	29	12	82
	8.0-11.9	11	20	20	61	93	62	267
	12.0-15.9	13	14	9	48	35	40	159
	16.0-19.9	8	0	2	24	29	47	110
	20.0+	0	12	7	31	32	20	102
Total		68	101	84	346	408	382	1389
Private 2/	3.1- 3.9	11	13	16	51	79	40	210
	4.0- 4.9	9	12	9	32	28	14	104
	5.0- 5.9	4	7	6	20	16	6	59
	6.0- 6.9	6	11	9	27	19	8	80
	7.0- 7.9	0	6	6	23	10	5	50
	8.0-11.9	12	23	20	50	42	29	176
	12.0-15.9	9	14	12	36	36	21	128
	16.0-19.9	5	4	10	13	32	8	72
	20.0+	15	26	14	14	32	32	133
Total		71	116	102	266	294	163	1012
Lodgepole pine 3/	3.1- 3.9	17	22	23	92	150	92	396
	4.0- 4.9	24	30	19	53	62	28	216
	5.0- 5.9	8	16	13	34	32	16	119
	6.0- 6.9	14	18	15	23	41	35	146
	7.0- 7.9	3	5	10	24	24	6	72
	8.0-11.9	13	32	17	56	68	27	213
	12.0-15.9	10	6	8	15	12	8	59
	16.0-19.9	0	4	3	21	16	3	47
	20.0+	0	0	0	15	0	15	30
Total		89	133	108	333	405	230	1298

1/ Does not include residue in large piles.

2/ Samples were selected from all harvest methods; most samples were from partial-cut areas.

3/ Samples were selected from all harvest methods and ownership classes.

The data in tables 5 and 6 can be used to determine the relationship between gross and net residue volume for any size class, or above or below a certain utilization standard. For example, the following tabulation compares gross and net volume for two size categories on public clearcuts in Montana:

Diameter/length class	Residue volume: Gross	Residue volume: Net
	(CF/AC)	
Diameter: 3.1-3.9 inches Length: 8.0-15.9 feet	105	102
Diameter: 16.0-19.9 inches Length: 8.0-15.9 feet	43	17

Table 6—Net volume (wood only) of logging residue, by diameter and length classes and by stratum[1/]

Stratum	Small end diameter	Length (feet) 1.0-3.9	4.0-5.9	6.0-7.9	8.0-15.9	16.0-31.9	32.0+	Total
	Inches	Cubic feet per acre						
Public:								
Clearcut	3.1- 3.9	9	21	27	102	138	76	373
	4.0- 4.9	13	16	14	37	48	19	147
	5.0- 5.9	4	11	11	29	18	10	83
	6.0- 6.9	11	8	7	28	25	19	98
	7.0- 7.9	2	3	9	13	12	7	46
	8.0-11.9	5	10	18	44	33	25	135
	12.0-15.9	6	3	8	20	18	12	67
	16.0-19.9	1	0	2	17	14	5	39
	20.0+	3	5	0	0	6	1	15
Total		54	77	96	290	312	174	1003
Partial cut	3.1- 3.9	5	11	9	53	68	61	207
	4.0- 4.9	5	9	5	28	28	31	106
	5.0- 5.9	2	5	7	15	12	9	50
	6.0- 6.9	4	4	5	15	20	29	77
	7.0- 7.9	1	3	3	8	10	8	33
	8.0-11.9	4	8	8	27	36	32	115
	12.0-15.9	10	6	4	21	13	10	64
	16.0-19.9	6	0	0	9	8	17	40
	20.0+	0	9	6	10	4	8	37
Total		37	55	47	186	199	205	729
Private 2/	3.1- 3.9	8	10	12	45	71	37	183
	4.0- 4.9	5	7	6	25	22	9	74
	5.0- 5.9	1	4	5	14	11	3	38
	6.0- 6.9	1	6	5	15	10	4	41
	7.0- 7.9	0	3	2	11	5	3	24
	8.0-11.9	6	11	11	21	20	13	82
	12.0-15.9	8	6	6	10	9	5	44
	16.0-19.9	2	1	5	2	9	1	20
	20.0+	5	16	5	3	19	3	51
Total		36	64	57	146	176	78	557
Lodgepole pine 3/	3.0- 3.9	12	19	17	79	133	77	337
	4.0- 4.9	15	20	14	41	46	20	156
	5.0- 5.9	4	10	8	22	21	9	74
	6.0- 6.9	7	9	11	12	22	17	78
	7.0- 7.9	1	4	5	15	16	3	44
	8.0-11.9	7	16	11	31	28	9	102
	12.0-15.9	9	3	2	8	3	1	26
	16.0-19.9	0	3	3	5	10	1	22
	20.0+	0	0	0	9	0	0	9
Total		55	84	71	222	279	137	848

1/ Does not include residue in large piles.

2/ Samples were selected from all harvest methods; most samples were from partial-cut areas.

3/ Samples were selected from all harvest methods and ownership classes.

In this example nearly all the gross volume (about 93 percent) in the smaller diameter class (3.1 to 3.9 inches) is sound. But in the larger diameter class only 17 cubic feet, or 40 percent, of the gross volume is chippable. This type of information is critical in evaluating the net fiber cost when assessing utilization of residue materials.

The relatively small diameter of lodgepole pine timber is a factor in its utilization as timber and as residue. Table 5 shows that only 27 percent of the residue in the lodgepole pine stratum is 8 inches or greater in diameter, small end. For the other three strata, residue 8 inches or greater makes up 41 to 49 percent of total gross volume.

Tables 13 through 16 in the appendix provide additional data on the portion of residue that was live, or dead or cull at the time of harvest. This information may be especially significant if product options differ for green versus dead or cull material.

Percent chippable.—The suitability of logging residue for a given product usually depends on physical characteristics of the material. A key factor is the nature and amount of defect acceptable for a given type of product. Checking and splitting, for example, make wood less suitable for sawn products but have no effect on the quantity or quality of wood chips. Likewise, decay beyond the very early stages may prohibit use for pulp but not necessarily for energy.

Assessment of the cost and returns of converting residue into a particular product requires that the acceptable level of defect be defined. Material that does not meet this standard is rejected as having too little usable content to justify the cost of handling and processing. The data presented in table 7 can be used in making this evaluation. Gross and net volume of scattered residue are given for seven classes of chippability. These data can be applied to figures in tables 5 and 6 to further refine estimates of residue volume that can be considered economically available.

Following is an example of how to interpret the data in table 7. In the private stratum gross volume of residue in the 61- to 80-percent-chippable class is 86 cubic feet per acre. Net volume for this class is 60 cubic feet per acre. Thus, 86 cubic feet would have to be processed to recover 60 cubic feet of usable wood fiber. This net volume is not synonymous with recovery of solid wood products because defects such as cracks, splits, and early stages of decay greatly reduce usability for these products. Therefore, the data in table 7 cannot be used to make precise assessments of solid product potential.

Table 7—Gross and net volume (wood) of logging residue, by percent of chippable material and by stratum[1]

Stratum	Volume	Percent chippable							
		0	1-20	21-40	41-60	61-80	81-99	100	Total
		Cubic feet per acre							
Public:									
Clearcut	Gross	142	236	129	115	127	285	539	1573
	Net	0	24	39	57	88	256	539	1003
Partial cut	Gross	172	295	151	117	119	219	316	1389
	Net	0	29	45	58	83	198	316	729
Private 2/	Gross	120	208	95	85	86	126	292	1012
	Net	0	21	29	42	60	113	292	557
Lodgepole pine 3/	Gross	94	197	90	102	108	314	393	1298
	Net	0	20	27	51	76	281	393	848

1/ Does not include residue in large piles.

2/ Samples were selected from all harvest methods; most samples were from partial-cut areas.

3/ Samples were selected from all harvest methods and ownership classes.

Number of pieces per acre.—The cost of retrieving residue material is a critical factor in decisions about utilization. Because equipment needs and costs of handling residue vary considerably, it is necessary to know number of pieces and volume by size classes. This information is provided by table 8. Tables 17 and 18 in the appendix show number of pieces per acre by live versus dead or cull.

Because the data in table 8 are averages for each stratum, the tabulations include fractions of pieces. In actuality, certain diameter or length classes may be represented on some cutover areas but not on others. This is particularly true for the larger size classes. What is important, however, is whether there are few or many pieces of a given size.

Volume per piece may be important in some assessments of logging residue. Tables 5 and 8 can be used to estimate the average gross volume per piece by dividing the volume of residue in a specific diameter and length class by the number of pieces in that class. For example, table 5 shows that in the private stratum pieces 3.1 to 3.9 inches in diameter and 6.0 to 7.9 feet long have a gross volume of 16 cubic feet per acre. Table 8 shows that for the same size class there are 17.0 pieces per acre. Therefore, the average volume per piece is about 0.94 cubic feet. Table 6 can be used to find the net volume per piece in a similar fashion.

An interesting comparison between volume per acre and number of pieces per acre can be made by using data from tables 5 and 8. The tabulation below compares the gross volume (table 5) of residue less than 6 inches in diameter with the number of pieces (table 8) less than 6 inches in diameter. Residue less than 6 inches made up the following percentages of stratum totals:

Stratum	Percent of gross volume	Percent of total pieces per acre
Public:		
Clearcut	44	79
Partial cut	37	74
Private	37	77
Lodgepole pine	56	83

These results show that although the number of pieces of residue less than 6 inches is quite high, the volume in these pieces constitutes less than half the total gross volume. The lone exception is the lodgepole pine stratum, where both figures are higher than for the other strata.

Product potentials.—In Montana there is an active market for house logs, posts, and poles. Because of this, options for utilizing logging residue frequently include recovery of these higher value products. With this situation in mind, residue in the subsample was recorded in one of three categories of product potential, as defined earlier in this report (table 9). It is important to bear in mind, however, that the minimum standards had to be met for only a portion of each piece; a piece of residue could meet the standard for house logs for part of its length, yet be classed as a post, pole, or fiber log for the remaining portion. In all cases the product of highest value was recorded for each piece.

The breakdown of live versus dead or cull shown in table 9 was provided for situations where quality considerations might dictate use of live material only. As in the previous tables in this section, large piles are excluded.

Residue distribution.—The distribution of residue over harvested areas is important in decisions concerning equipment needed to utilize these materials. Two factors that affect the type of equipment used to retrieve residue are slope and distance to the nearest road. The degree of slope on the harvested area determines whether ground-based or cable systems are required to yard the residue. Equipment limitations, such as maximum yarding distance, are determined by distance from the landing at roadside. As a rule, relogging does not recover the cost of new road construction, thus roads built during initial logging will generally be used for residue recovery operations.

Table 10 gives the average distribution of logging residue on cutover areas by slope and distance to the nearest road. This table includes residue in large piles, which are usually located adjacent to roads.

Table 8—Average number of pieces of logging residue per acre, by diameter and length classes and by stratum[1/]

Stratum	Small end diameter	Length classes (feet) 1.0-3.9	4.0-5.9	6.0-7.9	8.0-15.9	16.0-31.9	32.0+	Total
	Inches	Number of pieces per acre						
Public:								
Clearcut	3.1- 3.9	18.0	34.4	33.2	99.3	113.1	46.2	344.2
	4.0- 4.9	19.7	17.3	13.3	30.0	30.3	9.1	119.7
	5.0- 5.9	4.5	8.6	6.3	17.4	8.8	4.1	49.7
	6.0- 6.9	10.0	6.7	4.4	14.0	12.5	5.6	53.2
	7.0- 7.9	1.2	1.6	3.5	5.5	3.8	1.7	17.3
	8.0-11.9	3.5	6.2	5.2	11.6	9.7	4.7	40.9
	12.0-15.9	1.1	1.6	1.5	3.3	3.1	2.0	12.6
	16.0-19.9	.3	0	.9	2.2	1.5	.9	5.8
	20.0+	.2	.4	0	.5	1.4	.5	3.0
Total		58.5	76.8	68.3	183.8	184.2	74.8	646.4
Partial cut	3.1- 3.9	11.8	20.6	15.5	64.8	70.1	38.8	221.6
	4.0- 4.9	9.7	11.6	6.3	26.0	21.4	16.8	91.8
	5.0- 5.9	1.7	5.5	5.1	9.8	8.7	6.3	37.1
	6.0- 6.9	3.2	3.4	3.7	11.6	10.3	9.4	41.6
	7.0- 7.9	2.0	2.1	1.4	5.6	7.0	2.4	20.5
	8.0-11.9	2.4	3.7	3.4	9.6	13.2	6.9	39.2
	12.0-15.9	1.3	1.2	.6	3.7	3.1	2.3	12.2
	16.0-19.9	.4	0	.2	1.3	1.4	1.7	5.0
	20.0+	0	.3	.2	1.0	.7	.4	2.6
Total		32.5	48.4	36.4	133.4	135.9	85.0	471.6
Private 2/	3.1- 3.9	17.0	17.9	17.0	49.4	59.5	20.7	181.5
	4.0- 4.9	9.3	9.5	7.7	20.1	14.3	4.4	65.3
	5.0- 5.9	2.4	3.4	2.8	9.4	5.6	1.9	25.6
	6.0- 6.9	2.4	4.4	3.0	9.4	5.5	1.5	26.2
	7.0- 7.9	.2	1.6	1.4	5.3	2.3	1.2	12.0
	8.0-11.9	2.2	3.6	3.1	8.1	6.0	3.5	26.5
	12.0-15.9	.8	1.3	1.0	2.9	2.7	1.3	10.0
	16.0-19.9	.3	.2	.4	.7	1.3	.4	3.3
	20.0+	.4	.6	.3	.4	.8	.6	3.1
Total		35.0	42.5	36.7	105.7	98.1	35.5	353.5
Lodgepole pine 3/	3.1- 3.9	25.3	31.2	26.9	92.3	118.2	52.2	346.1
	4.0- 4.9	22.7	25.0	15.2	36.1	34.5	10.9	144.4
	5.0- 5.9	4.3	9.2	6.7	16.2	13.0	4.9	54.3
	6.0- 6.9	6.3	7.8	5.0	8.1	10.8	5.7	43.7
	7.0- 7.9	.8	1.4	2.6	6.7	5.0	1.2	17.7
	8.0-11.9	2.8	6.3	3.3	8.6	9.5	3.4	33.9
	12.0-15.9	1.1	.4	.6	1.2	1.0	.4	4.7
	16.0-19.9	0	.3	.2	.7	.8	.2	2.2
	20.0+	0	0	0	.3	0	.5	.8
Total		63.3	81.6	60.4	170.2	192.8	79.5	647.8

1/ Does not include residue in large piles.

2/ Samples were selected from all harvest methods; most samples were from partial-cut areas.

3/ Samples were selected from all harvest methods and ownership classes.

Table 9—Product potential of logging residue (wood only) by gross and net volume, live and dead or cull, and by stratum[1/]

Stratum	Product potential	Gross volume			Net volume		
		Live	Dead or cull	Total	Live	Dead or cull	Total
		Cubic feet per acre					
Public:							
Clearcut							
	Fiber	353	848	1201	284	347	631
	Post or pole	232	15	247	232	15	247
	House or sawlog	107	18	125	107	18	125
Total		692	881	1573	623	380	1003
Partial cut							
	Fiber	198	961	1159	154	356	510
	Post or pole	97	13	110	94	12	106
	House or sawlog	93	27	120	87	26	113
Total		388	1001	1389	335	394	729
Private 2/							
	Fiber	165	682	847	135	258	393
	Post or pole	98	6	104	98	5	103
	House or sawlog	57	4	61	57	4	61
Total		320	692	1012	290	267	557
Lodgepole pine 3/							
	Fiber	201	824	1025	176	412	588
	Post or pole	167	24	191	161	22	183
	House or sawlog	62	20	82	59	18	77
Total		430	868	1298	396	452	848

1/ Does not include residue in large piles.

2/ Samples were selected from all harvest methods; most samples were from partial-cut areas.

3/ Samples were selected from all harvest methods and ownership classes.

Table 10—Distribution of logging residue by slope and distance-to-road class and by stratum[1/]

Stratum	Percent slope	Distance to road (feet) 0-500	501-1,000	1,100	Total
		Percent			
Public:					
Clearcut	0-35	64.4	6.0	0.2	70.6
	36+	21.4	7.6	.4	29.4
Total		85.8	13.6	.6	100.0
Partial cut	0-35	50.3	17.7	2.3	70.3
	36+	20.4	5.6	3.7	29.7
Total		70.7	23.3	6.0	100.0
Private 2/	0-35	54.9	16.6	2.6	74.1
	36+	13.4	10.5	2.0	25.9
Total		68.3	27.1	4.6	100.0
Lodgepole pine 3/	0-35	74.0	13.2	1.2	88.4
	36+	9.6	2.0	.0	11.6
Total		83.6	15.2	1.2	100.0

1/ Includes residue in large piles which are usually, but not always, adjacent to a road.

2/ Samples were selected from all harvest methods; most samples were from partial-cut areas.

3/ Samples were selected from all harvest methods and ownership classes.

Application of Results

Ratios for estimating residue volume developed in this report have a variety of uses. A major use of these data will be for estimating the volume of residue expected from timber harvest activities within a uniquely defined supply zone. The following is a hypothetical example of using data in this report to generate an estimate of the volume of residue for a specific location.

In this example, an estimate of annual residue volume is needed for a feasibility study of a proposed wood-fired power generation facility in Columbia Falls, Montana. Figure 7 shows the proposed supply zone for this example. The boundaries are based on existing transportation systems, timber harvest patterns, and an assumed cost-effective haul distance for residue of 75 miles. Although some residue outside the supply zone may be cheaper to recover than some within the zone, no attempt is made to account for it in this example. Both wood and bark residue is considered acceptable as fuel for the proposed facility.

Two types of data are needed to estimate residue volume for the supply zone. These are (1) annual harvest volume or acreage for each stratum within the supply zone, and (2) appropriate residue ratios corresponding to the strata identified above. Harvest volumes must be determined from available timber harvest records. For this example, the ratio for net residue volume (wood and bark) is taken from table 1.

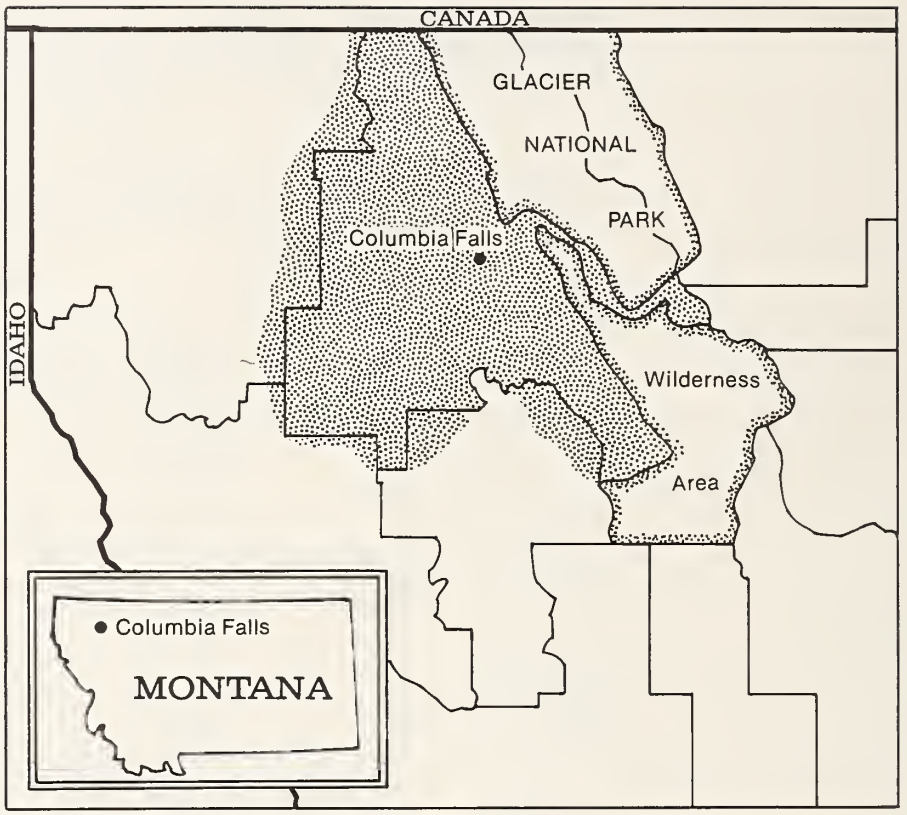


Figure 7.—Supply zone for a hypothetical wood-using facility located at Columbia Falls, Montana.

Shown below are the harvest volumes and residue ratios for the hypothetical example described.

Stratum	Annual harvest volume	Ratio of residue volume to harvest volume
	MBF	*CF/MBF*
Public:		
Clearcut	26,620	95
Partial cut	51,674	103
Private	93,424	137
Lodgepole pine	60,871	107

Volume of annual residue for the example can be estimated by multiplying the figures shown above as follows:

Public (clearcut)	26,620 × 95 =	2,528,900 cubic feet
Public (partial cut)	51,674 × 103 =	5,322,422 cubic feet
Private	93,424 × 137 =	12,799,088 cubic feet
Lodgepole pine	60,871 × 107 =	6,513,197 cubic feet
Total		27,163,607 cubic feet

Precision of Results

These computations show the annual residue volume for the supply zone in this hypothetical situation to be approximately 27 million cubic feet. The 27 million cubic feet of residue does not translate into an equivalent volume available for use. Other factors, such as future harvest levels, competition for available supplies, management objectives, and cost considerations play an important part in determining the amount of residue available for energy conversion. It is the responsibility of the analyst to determine this, but the above estimate provides a good baseline for a feasibility study.

The data in this report represent a new level of information on logging residue in Montana and issues related to site-specific analyses. These data provide a basis not previously available for assessing logging residue, but they do have limitations.

Table 11 gives the relevant statistical elements for determining precision of study results.

The indices of precision used here are based on gross wood volume of residue in cubic feet per acre (CF/AC), because the CF/AC volume of residue is the primary estimate provided by study measurements. Indices for CF/MBF ratios are not provided because they use timber harvest information provided by land owners. If errors in timber harvest volume exist, they are unknown.

Table 12 gives the range of study data for selected characteristics. This information is included to provide additional insight into the application of study results. It may also be useful if application is intended for areas beyond the scope of this report, for example, if the supply zone for a selected site includes geographic areas outside the boundaries of this study. If data in this report are the only available source, the information in table 12 may help determine their usefulness, but application should be restricted to the range of data indicated in table 12. The level of accuracy associated with the results of this report does not apply to extensions beyond the scope of the study.

Table 11—Statistical information for determining sampling precision by stratum

Stratum	Number of samples	Average gross volume (wood)	Standard error of the mean
		- - - Cubic feet per acre - - -	
Public:			
Clearcut	25	2021	215.3
Partial cut	35	1578	136.7
Private 1/	35	1345	148.4
Lodgepole pine 2/	25	1816	205.4

1/ Samples were selected from all harvest methods; most samples were from partial-cut areas.

2/ Samples were selected from all harvest methods and ownership classes.

Table 12—Range of study data for stand age, harvest volume, area cut, and residue volume, by stratum

Stratum	Sample characteristics			
	Stand age	Harvest volume	Area cut	Net wood residue volume
	Years	Thousand board feet per acre	Acres	Cubic feet per acre
Public:				
Clearcut	70-200	4-48	5-34	473-2816
Partial cut	60-200	1-48	5-282	185-2061
Private 1/	50-300	2-22	10-448	139-2624
Lodgepole pine 2/	70-180	1-29	8-230	341-2841

1/ Samples were selected from all harvest methods; most samples were from partial-cut areas.

2/ Samples were selected from all harvest methods and ownership classes.

Acknowledgments

This study was made possible by financial support from the U.S. Department of Energy, which had previously supported a study of logging residue in Idaho, Oregon, and Washington. The department joined the USDA Forest Service in recognizing the need to provide similar information for Montana.

The prompt and complete responses of private companies and public agencies to the inquiries of researchers contributed significantly to the success of the study.

Metric Equivalents

1 inch = 2.54 centimeters
1 foot = 30.48 centimeters
1 mile = 1.609 kilometers
1 acre = 0.405 hectare
1 cubic foot = 0.0283 cubic meter (stere)
1 pound = 0.454 kilogram
1 ton = 0.907 metric ton
1 British thermal unit (Btu) = 1,055.87 joules

Literature Cited

Arola, Roger A. Wood fuels—how do they stack up? In Energy and the wood products industry: proceedings of a symposium; 1976 November 15-17; Atlanta, GA. Madison, WI: Forest Products Research Society; **1977:**34-45.

Barger, Roland L.; Fiedler, Carl. The small timber resource in the inland west. In: Proceedings of Harvesting small timber-waste not, want not; **1981,** April 28-30; Syracuse, NY; Madison, WI. For. Prod. Res. Soc., T-81-32; **1981.** pp. 3-17.

Benson, Robert E.; Johnston, Cameron M. Logging residues under different stand and harvesting conditions. Res. Pap. INT-181. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. **1976:** 15 p.

Benson, Robert E.; Schlieter, Joyce A. Logging residues in principal forest types of the Northern Rocky Mountains. Res. Pap. INT-260. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; **1980.** 14 p.

Bergvall, John A.; Bullington, Darryl C.; Gee, Loren; Koss, William. Wood waste for energy study. Inventory assessment and economic analysis. Olympia, WA: State of Washington Department of Natural Resources; **1978.** 216 p.

Brown, James K.; See, Thomas E. Downed dead woody fuel and biomass in the northern Rocky Mountains. Gen. Tech. Rep. INT-117. Odgen, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; **1981.** 48 p.

Howard, James O.; Ward, Franklin R. Measurement of logging residue: alternative application of the line intersect method. Res. Note PNW-183. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; **1972.** 8 p.

Howard, James O. A technique for predicting logging residue volumes in the Douglas-fir region. Res. Pap. PNW-225. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; **1978.** 26 p.

Howard, James O. Ratios for estimating logging residue in the Pacific Northwest. Res. Pap. PNW-288. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; **1981a.** 26 p.

Howard, James O. Logging residue in the Pacific Northwest: characteristics affecting utilization. Res. Pap. PNW-289. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; **1981b.** 41 p.

Keegan, Charles E. III. The cost and availability of forest residues in the northern Rocky Mountains. Missoula, MT: Bureau of Business and Economic Research, School of Business, Univ. of Montana. **1981.** 51 p.

Little, Susan N. Estimating the volume of wood in large piles. Admin. Rep. PNW-1. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; **1982.** 7 p.

Pickford, Stewart G.; Hazard, John W. Simulation studies on line intersect sampling of forest residue. Forest Science 24(4): 469-483; **1978.**

Snell, J. A. Kendall; Max, Timothy A. Bark-to-wood ratios for logging residue in Oregon, Washington and Idaho. Admin. Rep. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; **1982.** 9 p.

U.S. Forest Products Laboratory. Wood handbook: wood as an engineering material. Agric. Handb. 72 (rev.). Washington, DC; U.S. Department of Agriculture, Forest Service; **1974.**

Appendix

Glossary[1]

Clearcut A harvest method in which all, or nearly all, of the trees in a stand of timber are cut in one operation.

Cutover area Synonymous with sample unit or sample area; the area encompassing a single harvest operation (example: a clearcut).

Diameter Diameter of residue pieces measured inside the bark (d.i.b.) at the point residue intersects a line transect.

Harvest volume Net scaled volume of timber removed from a cutover area during harvesting, expressed in thousand board feet (Scribner log scale) per acre (MBF/AC).

Line transect A vertical sampling plane with no width, along which all intersecting residue pieces are measured.

Logging residue

General All down and dead woody material existing on an area after timber harvest is completed.

Specific All logging residue (as defined above) 3.01 inches and larger inside bark (d.i.b.) and 1.0 foot and longer in length, including limbs, slabs, and splinters.

MBF 1,000 board feet of logs, a measure of the volume of timber harvested.

Owner class

Private Lands owned by private individuals, forest industries, or other corporations.

Public Lands owned by the public or managed by a public agency.

Partial cut A harvest method in which portions of a stand of timber are cut during a number of entries over time; precommercial thinnings are not included.

Product potential Classification of residue material as to its potential to yield (1) house or sawlog, (2) post or pole, and (3) fiber only.

Residue volume

Gross Volume of a piece of residue measured only by its external dimensions; includes rot, cracks, and missing parts.

Net The usable portion of a piece of residue; for this report usability is based on physical chippability of the material.

Chippability Condition of residue sound enough to be physically handled and capable of producing usable chips; includes residue exhibiting early stages of wet or dry rot.

Live Residue from trees that were alive before they were cut or knocked down during harvest.

Dead Residue from trees or portions of trees that were dead before harvest.

Cull Residue from trees that were cull (less than 25 percent sound) at the time of harvest.

Stratum A category of timber harvest area defined for this study by ownership class, harvest method, and forest type.

Supply zone A uniquely defined area containing a timber determined to be potentially available for a processing facility.

YUM (or PUM) piles Terms used by the USDA Forest Service for large piles of residue that have been yarded or bulldozed to a common location; if the residue has been piled with some degree of uniformity it is referred to as a PUM (piled unmerchantable material); otherwise, the term YUM (Yarded unmerchantable material) is used.

[1]Terms and abbreviations are defined as they are used in this report.

Wood Density and Heating Values for Selected Species

Species	Density (dry weight)[2] *(Pounds per cubic foot)*	Higher heating values (dry weight)[3] *(Btu per pound)*
Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco)	28	9,050
Western larch (*Larix occidentalis* Nutt.)	30	8,510
Ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.)	24	9,100
Lodgepole pine (*Pinus contorta* Dougl. ex Loud)	24	8,730
Western white pine (*Pinus monticola* Dougl. ex D. Don.)	22	—
Spruces (*Picea* spp.)	22	—
Western hemlock (*Tsuga heterophylla* (Raf.) Sarg.)	26	8,260
True firs (*Abies* spp.)	23	—
Western redcedar (*Thuja plicata* Donn. ex D. Don.)	19	9,700
Aspen (*Populus tremuloides* Michx.)	22	—
Red alder (*Alnus rubra* Bong.)	23	8,000
Black cottonwood (*Populus trichocarpa* (Torr. & Gray)	19	8,510

[2]U.S. Forest Products Laboratory (1974).

[3]Arola (1976); Bergvall and others (1978).

Table 13—Gross volume (wood only) of live logging residue by diameter and length classes and by stratum 1/

Stratum	Small end diameter	Length (feet)						
		1.0-3.9	4.0-5.9	6.0-7.9	8.0-15.9	16.0-31.9	32.0+	Total
	Inches	Cubic feet per acre						
Public:								
Clearcut	3.1- 3.9	7	16	24	91	124	60	322
	4.0- 4.9	9	11	8	29	36	9	102
	5.0- 5.9	3	8	8	20	10	5	54
	6.0- 6.9	14	8	4	18	10	11	65
	7.0- 7.9	1	2	5	7	4	3	22
	8.0-11.9	4	7	15	20	9	7	62
	12.0-15.9	8	2	8	6	14	0	38
	16.0-19.9	4	0	0	9	0	0	13
	20.0+	8	6	0	0	0	0	14
Total		58	60	72	200	207	95	692
Partial cut	3.1- 3.9	4	8	8	40	51	28	139
	4.0- 4.9	2	5	3	16	14	8	48
	5.0- 5.9	1	2	3	9	7	4	26
	6.0- 6.9	4	3	2	7	6	12	34
	7.0- 7.9	0	1	1	1	3	1	7
	8.0-11.9	2	5	3	12	7	10	39
	12.0-15.9	11	5	3	18	8	0	45
	16.0-19.9	8	0	0	11	2	2	23
	20.0+	0	7	7	4	9	0	27
Total		32	36	30	118	107	65	388
Private 2/	3.1- 3.9	5	7	9	36	61	31	149
	4.0- 4.9	2	4	4	18	14	3	45
	5.0- 5.9	0	2	4	6	5	0	17
	6.0- 6.9	1	4	2	8	3	1	19
	7.0- 7.9	0	3	0	5	2	2	12
	8.0-11.9	6	6	5	10	4	2	33
	12.0-15.9	8	0	4	8	3	0	23
	16.0-19.9	4	0	4	6	4	0	18
	20.0+	0	0	0	0	4	0	4
Total		26	26	32	97	100	39	320
Lodgepole pine 3/	3.1- 3.9	8	12	12	51	98	47	228
	4.0- 4.9	6	9	6	26	20	5	72
	5.0- 5.9	3	5	4	11	8	3	34
	6.0- 6.9	2	5	4	4	5	3	23
	7.0- 7.9	1	2	2	5	4	1	15
	8.0-11.9	4	7	4	10	8	3	36
	12.0-15.9	5	0	2	4	0	0	11
	16.0-19.9	0	4	0	3	4	0	11
	20.0+	0	0	0	0	0	0	0
Total		29	44	34	114	147	62	430

1/ Does not include residue in large piles.

2/ Samples were selected from all harvest methods; most samples were from partial-cut areas.

3/ Samples were selected from all harvest methods and ownership classes.

Table 14—Gross volume (wood only) of dead or cull logging residue by diameter and length classes and by stratum 1/

Stratum	Small end diameter	Length (feet)						
		1.0-3.9	4.0-5.9	6.0-7.9	8.0-15.9	16.0-31.9	32.0+	Total
	Inches	Cubic feet per acre						
Public:								
Clearcut	3.1- 3.9	5	8	7	18	19	23	80
	4.0- 4.9	11	11	8	14	17	14	75
	5.0- 5.9	4	9	5	19	15	9	61
	6.0- 6.9	10	8	8	21	29	15	91
	7.0- 7.9	2	4	8	15	12	8	49
	8.0-11.9	15	27	19	56	58	38	213
	12.0-15.9	4	14	11	32	27	33	121
	16.0-19.9	0	0	17	34	35	18	104
	20.0+	0	8	0	16	49	14	87
Total		51	89	83	225	261	172	881
Partial cut	3.1- 3.9	5	7	5	26	38	53	134
	4.0- 4.9	8	10	4	21	26	40	109
	5.0- 5.9	2	8	7	14	17	17	65
	6.0- 6.9	4	6	7	26	31	41	115
	7.0- 7.9	7	5	4	21	27	11	75
	8.0-11.9	9	14	17	49	86	52	227
	12.0-15.9	2	9	6	30	27	39	113
	16.0-19.9	0	0	2	12	27	45	86
	20.0+	0	6	0	27	23	21	77
Total		37	65	52	226	302	319	1001
Private 2/	3.1- 3.9	6	7	6	16	21	11	67
	4.0- 4.9	7	8	5	14	15	11	60
	5.0- 5.9	4	5	2	15	10	5	41
	6.0- 6.9	4	7	7	19	17	7	61
	7.0- 7.9	0	3	6	18	8	3	38
	8.0-11.9	5	17	16	40	37	27	142
	12.0-15.9	1	14	8	28	32	20	103
	16.0-19.9	2	4	5	8	27	8	54
	20.0+	15	25	14	13	27	32	126
Total		44	90	69	171	194	124	692
Lodgepole pine 3/	3.1- 3.9	10	10	11	41	51	43	166
	4.0- 4.9	18	21	13	27	42	24	145
	5.0- 5.9	4	11	9	23	24	13	84
	6.0- 6.9	12	13	11	18	37	32	123
	7.0- 7.9	1	3	8	20	21	5	58
	8.0-11.9	11	24	13	46	59	24	177
	12.0-15.9	4	6	6	11	12	9	48
	16.0-19.9	0	0	4	17	13	3	37
	20.0+	0	0	0	15	0	15	30
Total		60	88	75	218	259	168	868

1/ Does not include residue in large piles.

2/ Samples were selected from all harvest methods; most samples were from partial-cut areas.

3/ Samples were selected from all harvest methods and ownership classes.

Table 15—Net volume (wood only) of live logging residue by diameter and length classes and by stratum 1/

Stratum	Small end diameter	Length (feet)						
		1.0-3.9	4.0-5.9	6.0-7.9	8.0-15.9	16.0-31.9	32.0+	Total
	Inches	Cubic feet per acre						
Public:								
Clearcut	3.1- 3.9	7	16	23	90	123	57	316
	4.0- 4.9	7	9	8	27	35	8	94
	5.0- 5.9	3	6	8	18	9	5	49
	6.0- 6.9	9	6	3	17	10	10	55
	7.0- 7.9	1	1	5	4	4	3	18
	8.0-11.9	2	4	11	18	9	7	51
	12.0-15.9	4	2	4	6	7	0	23
	16.0-19.9	1	0	0	10	0	0	11
	20.0+	3	3	0	0	0	0	6
Total		37	47	62	190	197	90	623
Partial cut	3.1- 3.9	4	7	7	38	48	27	131
	4.0- 4.9	2	5	3	16	13	7	46
	5.0- 5.9	1	2	2	8	6	3	22
	6.0- 6.9	3	2	2	5	5	11	29
	7.0- 7.9	0	1	1	1	2	1	6
	8.0-11.9	2	4	2	10	6	10	34
	12.0-15.9	10	3	1	13	7	0	34
	16.0-19.9	6	0	0	6	1	1	14
	20.0+	0	6	6	4	3	0	19
Total		28	30	24	102	91	60	335
Private 2/	3.1- 3.9	5	7	9	36	60	31	148
	4.0- 4.9	2	4	4	18	13	3	44
	5.0- 5.9	0	2	4	6	5	0	17
	6.0- 6.9	1	3	2	7	3	1	17
	7.0- 7.9	0	2	0	5	2	2	11
	8.0-11.9	4	5	5	8	4	2	28
	12.0-15.9	7	0	3	3	1	0	14
	16.0-19.9	2	0	4	2	0	0	8
	20.0+	0	0	0	0	3	0	3
Total		21	23	31	85	91	39	290
Lodgepole pine 3/	3.1- 3.9	6	12	10	48	95	45	216
	4.0- 4.9	6	8	5	24	19	5	67
	5.0- 5.9	2	4	3	11	7	2	29
	6.0- 6.9	2	3	4	3	4	3	19
	7.0- 7.9	1	2	2	4	4	1	14
	8.0-11.9	3	7	4	8	6	3	31
	12.0-15.9	5	0	1	4	0	0	10
	16.0-19.9	0	3	0	3	4	0	10
	20.0+	0	0	0	0	0	0	0
Total		25	39	29	105	139	59	396

1/ Does not include residue in large piles.

2/ Samples were selected from all harvest methods; most samples were from partial-cut areas.

3/ Samples were selected from all harvest methods and ownership classes.

Table 16—Net volume (wood only) of dead or cull logging residue by diameter and length classes and by stratum 1/

Stratum	Small end diameter	Length (feet)						
		1.0-3.9	4.0-5.9	6.0-7.9	8.0-15.9	16.0-31.9	32.0+	Total
	Inches	Cubic feet per acre						
Public:								
Clearcut	3.1- 3.9	3	5	4	12	15	20	59
	4.0- 4.9	5	7	6	10	13	11	53
	5.0- 5.9	1	4	3	11	9	6	34
	6.0- 6.9	2	3	5	12	15	8	45
	7.0- 7.9	0	2	4	9	8	3	26
	8.0-11.9	3	5	6	26	25	18	83
	12.0-15.9	3	1	3	14	11	12	44
	16.0-19.9	0	0	2	8	13	5	28
	20.0+	0	2	0	0	6	1	9
Total		17	29	33	102	115	84	380
Partial cut	3.1- 3.9	2	4	3	15	20	34	78
	4.0- 4.9	3	4	2	12	15	24	60
	5.0- 5.9	0	4	4	7	7	6	28
	6.0- 6.9	1	2	3	9	14	18	47
	7.0- 7.9	1	2	2	7	7	7	26
	8.0-11.9	2	4	6	17	30	22	81
	12.0-15.9	0	3	3	8	5	10	29
	16.0-19.9	0	0	0	3	8	16	27
	20.0+	0	2	0	6	2	8	18
Total		9	25	23	84	108	145	394
Private 2/	3.1- 3.9	3	4	3	10	13	7	40
	4.0- 4.9	3	3	2	8	8	5	29
	5.0- 5.9	1	2	1	8	6	3	21
	6.0- 6.9	0	2	3	8	7	3	23
	7.0- 7.9	0	1	2	6	4	2	15
	8.0-11.9	1	5	7	13	16	10	52
	12.0-15.9	0	5	3	7	7	5	27
	16.0-19.9	1	1	1	1	8	1	13
	20.0+	5	16	5	3	15	3	47
Total		14	39	27	64	84	39	267
Lodgepole pine 3/	3.1- 3.9	6	7	7	30	35	32	117
	4.0- 4.9	9	13	8	17	27	16	90
	5.0- 5.9	1	6	5	12	15	7	46
	6.0- 6.9	5	6	8	9	19	14	61
	7.0- 7.9	0	2	3	11	13	2	31
	8.0-11.9	4	8	7	23	22	7	71
	12.0-15.9	4	3	1	4	3	1	16
	16.0-19.9	0	0	3	1	6	1	11
	20.0+	0	0	0	9	0	0	9
Total		29	45	42	116	140	80	452

1/ Does not include residue in large piles.

2/ Samples were selected from all harvest methods; most samples were from partial-cut areas.

3/ Samples were selected from all harvest methods and ownership classes.

Table 17—Number of live pieces of logging residue per acre, by diameter and length classes and by stratum 1/

Stratum	Small end diameter	Length (feet)						
		1.0-3.9	4.0-5.9	6.0-7.9	8.0-15.9	16.0-31.9	32.0+	Total
	Inches	Number of pieces per acre						
Public:								
Clearcut	3.1- 3.9	10.3	23.0	26.2	85.2	101.9	37.1	283.7
	4.0- 4.9	8.5	7.9	6.5	19.3	20.2	3.7	66.1
	5.0- 5.9	1.8	4.0	4.0	9.0	3.7	1.5	24.0
	6.0- 6.9	5.8	3.3	1.5	6.4	3.5	1.8	22.3
	7.0- 7.9	.4	.4	1.4	1.7	1.0	.5	5.4
	8.0-11.9	.8	1.1	2.3	3.3	1.4	.5	9.3
	12.0-15.9	.7	.3	.7	.4	.9	0	3.0
	16.0-19.9	.3	0	0	.4	0	0	.7
	20.0+	.3	.3	0	0	0	0	.6
Total		28.9	40.3	42.6	125.7	132.6	45.0	415.1
Partial cut	3.1- 3.9	5.5	10.5	9.6	38.7	39.4	13.6	117.4
	4.0- 4.9	2.2	4.1	2.6	11.3	7.5	3.0	30.7
	5.0- 5.9	.5	1.3	1.3	3.9	2.3	1.1	10.4
	6.0- 6.9	1.3	1.0	.8	2.4	1.3	1.6	8.4
	7.0- 7.9	0	.4	.5	.5	.6	.1	2.1
	8.0-11.9	.4	.9	.4	2.1	.9	1.0	5.7
	12.0-15.9	1.0	.3	.2	1.4	.7	0	3.6
	16.0-19.9	.4	0	0	.6	.2	.1	1.3
	20.0+	0	.2	.2	.2	.1	0	.7
Total		11.4	18.7	15.6	61.1	53.0	20.5	180.3
Private 2/	3.1- 3.9	8.1	9.5	11.0	33.6	46.5	16.6	125.3
	4.0- 4.9	2.3	3.0	3.4	10.9	7.6	1.3	28.5
	5.0- 5.9	.3	1.4	2.0	2.7	1.6	.1	8.1
	6.0- 6.9	.6	1.4	.6	2.8	.7	.2	6.3
	7.0- 7.9	0	.7	0	1.1	.3	.5	2.6
	8.0-11.9	1.2	.6	.6	1.4	.6	.4	4.8
	12.0-15.9	.7	0	.3	.5	.2	0	1.7
	16.0-19.9	.1	0	.2	.3	.1	0	.7
	20.0+	0	0	0	0	.2	0	.2
Total		13.3	16.6	18.1	53.3	57.8	19.1	178.2
Lodgepole pine 3/	3.1- 3.9	10.5	16.8	14.4	52.0	79.1	30.8	203.6
	4.0- 4.9	5.7	7.6	4.7	17.7	12.8	2.1	50.6
	5.0- 5.9	1.9	3.1	1.8	5.5	3.7	1.2	17.2
	6.0- 6.9	.8	2.0	1.3	1.6	1.5	.4	7.6
	7.0- 7.9	.4	.6	.5	1.3	.6	.2	3.7
	8.0-11.9	.6	1.5	1.1	1.8	1.1	.4	6.5
	12.0-15.9	.5	0	.3	.5	0	0	1.3
	16.0-19.9	0	.2	0	.2	.2	0	.6
	20.0+	0	0	0	0	0	0	0
Total		20.4	31.9	24.1	80.6	99.0	35.1	291.1

1/ Does not include residue in large piles.

2/ Samples were selected from all harvest methods; most samples were from partial-cut areas.

3/ Samples were selected from all harvest methods and ownership classes.

Table 18—Number of dead or cull pieces of logging residue per acre, by diameter and length of classes and by stratum 1/

Stratum	Small end diameter	Length (feet)						
		1.0-3.9	4.0-5.9	6.0-7.9	8.0-15.9	16.0-31.9	32.0+	Total
	Inches	Number of pieces per acre						
Public:								
Clearcut	3.1- 3.9	7.7	11.4	7.0	14.1	11.2	9.1	60.5
	4.0- 4.9	11.2	9.4	6.8	10.7	10.1	5.4	53.6
	5.0- 5.9	2.7	4.6	2.3	8.4	5.1	2.6	25.7
	6.0- 6.9	4.2	3.4	2.9	7.6	9.0	3.8	30.9
	7.0- 7.9	.8	1.2	2.1	3.8	2.8	1.2	11.9
	8.0-11.9	2.7	5.1	2.9	8.3	8.3	4.2	31.6
	12.0-15.9	.3	1.2	.8	2.9	2.2	2.0	9.5
	16.0-19.9	0	0	.9	1.8	1.5	.9	5.1
	20.0+	0	.1	0	.5	1.4	.5	2.5
Total		29.6	36.5	25.7	58.1	51.6	29.8	231.3
Partial cut	3.1- 3.9	6.3	10.1	5.9	26.1	30.7	25.2	104.2
	4.0- 4.9	7.5	7.5	3.7	14.7	13.9	13.8	61.1
	5.0- 5.9	1.2	4.2	3.8	5.9	6.4	5.2	26.7
	6.0- 6.9	1.9	2.4	2.9	9.2	9.0	7.8	33.2
	7.0- 7.9	2.0	1.7	.9	5.1	6.4	2.3	18.4
	8.0-11.9	2.0	2.8	3.0	7.5	12.3	5.9	33.5
	12.0-15.9	.3	.9	.4	2.7	2.4	2.3	8.6
	16.0-19.9	0	0	.2	.7	1.2	1.6	3.7
	20.0+	0	.1	0	.8	.6	.4	1.9
Total		21.1	29.7	20.8	72.3	82.9	64.5	291.3
Private 2/	3.1- 3.9	8.9	8.4	6.0	15.8	13.0	4.1	56.2
	4.0- 4.9	7.0	6.5	4.3	9.2	6.7	3.1	36.8
	5.0- 5.9	2.1	2.0	.8	6.7	4.0	1.8	17.5
	6.0- 6.9	1.8	3.0	2.4	6.6	4.8	1.3	19.9
	7.0- 7.9	.2	.9	1.4	4.2	2.0	.7	9.4
	8.0-11.9	1.0	3.0	2.5	6.7	5.4	3.1	21.7
	12.0-15.9	.1	1.3	.7	2.4	2.5	1.3	8.3
	16.0-19.9	.2	.2	.2	.4	1.1	.4	2.6
	20.0+	.4	.6	.3	.4	.6	.6	2.9
Total		21.7	47.6	18.6	52.4	40.3	16.4	175.3
Lodgepole pine 3/	3.1- 3.9	14.8	14.4	12.5	40.3	39.1	21.4	142.5
	4.0- 4.9	17.0	17.4	10.5	18.4	21.7	8.8	93.8
	5.0- 5.9	2.4	6.1	4.9	10.7	9.3	3.7	37.1
	6.0- 6.9	5.5	5.8	3.7	6.5	9.3	5.3	36.1
	7.0- 7.9	.4	.8	2.1	5.4	4.4	1.0	14.0
	8.0-11.9	2.2	4.8	2.2	6.8	8.4	3.0	27.4
	12.0-15.9	.6	.4	.3	.7	1.0	.4	3.4
	16.0-19.9	0	.1	.2	.5	.6	.2	1.6
	20.0+	0	0	0	.3	0	.5	.8
Total		42.9	49.7	36.3	89.6	93.8	44.4	356.7

1/ Does not include residue in large piles.

2/ Samples were selected from all harvest methods; most samples were from partial-cut areas.

3/ Samples were selected from all harvest methods and ownership classes.

Table 19—Average net volume (wood and bark) of logging residue by area, owner class, and harvest method, per thousand board feet of timber harvest in Idaho, Oregon, and Washington

Area and owner class	Harvest method	
	Clearcut	Partial cut
	Cubic feet per thousand board feet	
Idaho:		
National Forest	87	122
Other public	--	1/ 142
Private	--	T/ 109
Western Oregon:		
National Forest	47	2/ 136
Other public	52	93
Private	40	296
Western Washington		
National Forest	44	2/ 136
Other public	51	118
Private	37	140
Eastern Oregon		
Public	--	1/ 76
Private	--	T/ 80
Eastern Washington		
Public	--	1/ 96
Private	--	T/ 72

-- means not applicable.

1/ Samples selected randomly from all areas harvested since January 1, 1979; most samples were from partial-cut areas, the predominant practice in this stratum.

2/ An average for cutover areas in western Oregon and western Washington; these strata were combined because of an inadequate sample population in western Washington.

Source: Howard 1981a.

Table 20—Average net volume (wood and bark) of logging residue by area, owner class, and harvest method in Idaho, Oregon, and Washington

Area and owner class	Harvest method	
	Clearcut	Partial cut
	Cubic feet per acre	
Idaho:		
National Forest	2,182	1,701
Other public	--	1/ 1,182
Private	--	1/ 824
Western Oregon:		
National Forest	2,471	2/ 1,488
Other public	2,642	1,184
Private	2,070	1,537
Western Washington		
National Forest	2,497	2/ 1,488
Other public	2,110	895
Private	1,331	992
Eastern Oregon		
Public	--	1/ 553
Private	--	1/ 534
Eastern Washington		
Public	--	1/ 670
Private	--	1/ 394

-- means not applicable.

1/ Samples selected randomly from all areas harvested since January 1, 1979; most samples were from partial-cut areas, the predominant practice in this stratum.

2/ An average for cutover areas in western Oregon and western Washington; these strata were combined because of an inadequate sample population in western Washington.

Source: Howard 1981a.

Howard, James O.; Fiedler, Carl E. Estimators and characteristics of logging residue in Montana. Res. Pap. PNW-321. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; **1984.** 29 p.

Ratios are presented for estimating volume and characteristics of logging residue in Montana. They relate cubic-foot volume of residue to thousand board feet of timber harvested and to acres harvested. Tables show gross and net volume of residue, with and without bark; by diameter and length classes; by number of pieces per acre; by percent soundness, by product potential, and by degree of slope and distance to roads.

Keywords: Residue estimation, residue measurements, slash, volume estimation, slash utilization, residue management, Montana.

The **Forest Service** of the U.S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives — as directed by Congress — to provide increasingly greater service to a growing Nation.

Pacific Northwest Forest and Range
Experiment Station
319 S.W. Pine St.
P.O. Box 3890
Portland, Oregon 97208